BORON

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Boron, a nonmetal, has atomic number 5 and is in periodic group 13. Elemental boron is a dark brown powder in the amorphous form and a yellowish-brown hard, brittle solid in the monoclinic crystalline form. Elemental boron is marketed in grades from 90% to 99% purity. Borax is a white crystalline substance chemically known as sodium tetraborate decahydrate and found in nature as the mineral tincal. Boric acid is a white, colorless crystalline solid sold in technical national formulary and special quality grades as granules or powder. Boron oxide is a colorless hard, brittle, solid resembling glass that is ground and marketed most often under the name anhydrous boric acid.

Boron ore produced domestically during 2004 totaled 1.2 million metric tons (Mt) valued at $626 million (table 1). The boron oxide (B_2O_3) content was 637,000 metric tons (t). The most common minerals of commercial importance in the United States were colemanite, kernite, tincal, and ulexite (table 2). Boron compounds and minerals were produced by surface and underground mining and from brine. U.S. consumption of minerals and compounds amounted to 385,000 t of boron oxide content (table 3). Boron products are priced and sold based on the boric oxide content, which varies by ore and compound, and on the absence or presence of sodium and calcium (table 4). Boron compounds exported by producers were boric acid (61,000 t) and sodium borate (135,000 t) (tables 1, 5). Boron imports consisted primarily of borax, boric acid, colemanite, and ulexite (tables 1, 5-6). Turkey and the United States were the world's leading producers of boron minerals (table 7).

Legislation and Government Programs

Magnetic levitation (maglev) is an advanced transportation technology in which magnetic forces lift, propel, and guide a vehicle on a specially designed guideway. Boron is used in the superconducting and other high-intensity magnets in this system. The U.S. Congress has continued to fund further planning for four maglev projects that totaled $4.5 billion in 2003 and $4.8 billion in 2004 (Federal Railroad Administration, 2004§[1]).

Zinc borate is a fire retardant material that can be added to petroleum-based products to make them resist fire. The State of California enacted laws that require upholstered furniture to resist ignition by small open flames, such as matches and cigarettes.

On November 1, the Consumer Product Safety Commission announced a nationwide draft flammability standard for all mattresses sold in the United States, which follows the new California TB 603 standard in most respects. Several mattress manufacturers had already implemented changes to make current production compliant. The National Institute of Standards and Technology indicated peak heat release will be limited in open flame ignitions, will minimize flashover, and will provide occupants 10 to 15 minutes to escape. The Commission voted unanimously on December 21 to issue a proposed safety standard to reduce deaths and injuries from fires involving mattresses. The proposed standard for mattresses addresses fires ignited by an open flame (U.S. Consumer Product Safety Commission, 2004§).

The National Center for Environmental Assessment (NCEA) announced that people can safely consume more than twice the amount of boron previously considered harmless [14 milligrams per day (mg/d) from 6.3 mg/d]. The NCEA is the division of the U.S. Environmental Protection Agency charged with assessing health risks associated with substances found in the environment (U.S. Environmental Protection Agency, 2004§).

Production

More than 200 minerals contain boric oxide, but only a few were of commercial importance (table 2). Four minerals make up almost 90% of the borates used by industry worldwide; they are sodium borates borax, kernite, calcium borate colemanite, and sodium-calcium borate ulexite. These minerals were extracted primarily in California and Turkey and to a lesser extent in Argentina, Bolivia, Chile, China, and Peru.

Domestic data for boron were derived by the U.S. Geological Survey from a voluntary survey of four U.S. operations. The majority of boron production continued to be from Kern County, CA, with the balance from San Bernardino and Inyo Counties, CA. All four operations to which a survey request was sent responded, representing 100% of the total boron produced and consumed (tables 1, 3).

American Borate Co. mined small amounts of colemanite and ulexite-probertite underground at the Billie Mine in Death Valley, CA. The ore was transported to Lathrop Well, NV, for processing. Storage and grinding facilities were at Dunn, CA. Export was primarily to Asian markets.

Fort Cady Minerals Corp. used an in situ process near Hector, CA, to produce a product that contained 48% boron oxide. During 2004, the plant was idle but product in storage was being marketed. The company had hired consultants to assess the market for boron oxide derivatives and whether additional downstream plants should be built to market boron compounds, and assessment was ongoing during 2004.

[1]References that include a section mark (§) are found in the Internet References Cited section.

On March 23, IMC Global Inc. sold IMC Chemicals Inc. to Sun Capital Partners, Inc. of Boca Raton, FL. Sun Capital purchased the soda ash and boron chemicals operations in California's Searles Valley. As a result of the sale, the company changed its name to Searles Valley Minerals, Inc. IMC Global's specialty borates plant in Lardellero, Italy, was purchased by Tuscan Stars GSA, LLC and some of its affiliates. IMC Global retained about 20% equity interest in IMC Chemical (IMC Global Inc., 2004).

U.S. Borax, Inc. (a wholly owned subsidiary of London, United Kingdom-based Rio Tinto plc) mined borate ores at Boron, CA, by open pit methods and transported the ores to a storage area by trucks. Global positioning system (GPS)-based machine guidance technology was used to boost safety on an electric shovel used to load the trucks. The positions calculated were accurate to between 25 and 50 millimeters. The GPS position was compared to a computer generated model of the desired finished terrain and provided visual guidance to the operator. Triangulation and grid files were used to calculate excavated volume on a shift-by-shift basis. The GPS system gave equipment operators the tools they needed to work safely in potentially hazardous areas. Because three underground mines operated in the mine area prior to 1927, when the site became an open pit, pillar collapse, water percolation, and hanging wall failure have caused unstable ground. Hazardous areas were cordoned off and exploration holes were drilled to detect voids and confirm the location of underground stopes. When a void was found, the area was blasted to collapse and close it. Redrilling confirmed no new voids (Mining Engineering, 2004).

The ore was processed into sodium borate or boric acid products in the refinery complex adjacent to the mine. An onsite plant also produced anhydrous sodium borate and boric oxide. Refinery products were shipped by railcar or truck to North American customers or to the U.S. Borax Wilmington, CA, facility at the Port of Los Angeles for international distribution. In addition to its refinery and shipping terminal in Wilmington, U.S. Borax has its global headquarters in Valencia, CA, and its Owens Lake, CA, trona mine supplies raw material to the Boron, CA, refinery. U.S. Borax's Owens Lake operation allowed the company to ensure control of the trona supply used in the borate refining process. Trona provided a cost-effective source of carbonates, which helped reduce scaling in the processing equipment. Multiyear labor agreements that will provide additional operational flexibility and efficiency were negotiated at U.S. Borax's U.S. operations.

Consumption

Agriculture.—Boron is 1 of 16 nutrients essential to all plants. Boron is necessary in plant reproduction, controlling flowering, pollen production, germination, and fruit development. Domestic consumption was 2% in fertilizer usage. Boron is essential to plant growth and can be applied as a spray and incorporated in fertilizer, herbicides, and irrigation water. Boron fertilizers can quadruple corn yields and increase cotton yields by more than 227 kilograms per acre (500 pounds per acre). Boron deficiencies in crops are found primarily in soils low in organic matter and in acid, sandy soils in humid regions. Boron applied in May and June during early growth can be combined with calcium. For early season apples, boron can be applied post-harvest to provide adequate nutrition when buds begin to develop for blooming the next growing season. In the crop year ending June 30, 2004, 13,000 t (14,300 short tons) of boron micronutrients was applied on crops compared with 9,380 t (10,300 short tons) in crop year 2003. The leading consuming U.S. region in 2003 and 2004 was the Pacific, which used 4,460 t (4,920 short tons) and 4,356 t (4,800 short tons), respectively (Terry and Kirby, 2004, p. 37; 2005, p. 37).

Fire Retardants.—Zinc borate was used in plastics as a multifunctional boron-base fire retardant with applications in a variety of plastics and rubber compounds. Depending on the polymer used and fire standards to be met, zinc bromate can replace other fire-retardant additives, such as antimony oxide. Zinc bromate was normally used in conjunction with aluminum trihydrate, magnesium hydroxide, or a silicon polymer. Boric acid is used in cellulose insulation, in cotton mattresses, and in wood as a fire retardant.

Glass.—The glass industry, which remained the leading domestic market for boron production in 2004, accounted for 70% of boron consumption. Insulation-grade glass fibers accounted for an estimated 46% of domestic consumption; textile-grade glass fibers, 16%; borosilicate glasses, 5%; and enamels, frits, and glazes, 3%.

Soaps and Detergents.—Until 2001, sodium perborate consumed more than one-third of the peroxide used in the manufacture of inorganic chemicals. The use has declined because of environmental concerns about boron in wastewater. Sodium percarbonate can substitute for sodium perborate in laundry products (Kirschner, 2004).

Other.—Callery Chemical Division of Mine Safety Appliances Co., a leading manufacturer of elemental boron, was being acquired by BASF Corp. (the North American affiliate of BASF AG of Germany) (Oil & Gas Journal, 2004§). Boron carbide is used in military personnel body armor (Jacoby, 2004a).

Transportation

The Trona railway, connected to the Southern Pacific Railroad between Trona and Searles Stations, in California provided a dedicated line with access to the national rail systems for the borate and soda ash markets.

Almost all U.S. Borax bulk products were shipped in North America by rail. The Boron Mine at Boron is served solely by the Burlington Northern Santa Fe Railroad. In order to connect to another rail line, a transload or transfer point was set up in Cantil, CA, which is served by the Union Pacific Railroad. Trucks of product from Boron are driven to Cantil, about 64 kilometers (km) (40 miles) northwest of Boron, CA, and loaded into dedicated railcars to be shipped to customers.

Cross-country rail shipments are more cost effective in the United States than the use of ocean transportation. Prices for rail haulage depended on a number of factors including the ability of customers to load and unload efficiently, the ability to use whole unit trains, and the ability to supply their own railcars. The recent increase in fuel prices is another factor affecting cost with carriers passing on surcharges to customers.

Ocean transport of U.S. Borax products was from the Port of Wilmington, where the company had a privately owned berth in the harbor. Products destined for Europe were shipped from the bulk terminal in Wilmington to a company-owned facility in the Port of Rotterdam, Netherlands, to company facilities in Spain, and to contracted warehouses. Borax Group also maintains secondary stock points that include Austria, Germany, Norway, the Republic of Korea, Taiwan, and Ukraine. The most centrally located U.S. Borax port location in Europe was Antwerp, Belgium. The industrial minerals market in Europe was characterized by high volumes of imported materials, mostly forwarded through the industrialized areas of Belgium, France, Germany, and the Netherlands for destinations in Central Europe, such as Austria, the Czech Republic, and Slovenia. A decision to import borates was based on the geographic location, the range of service needed, and prices.

U.S. Borax used barges to ship borates from Rotterdam, Netherlands, to customers in Belgium, Eastern Europe, France, Germany, and countries even farther away. Barges were the most efficient and reliable method of transporting goods in Europe because most of the large industrial areas could be reached on waterways that link parts of the North, Baltic, Black, and Mediterranean Seas and the Atlantic Ocean.

Prices

Prices of boron minerals and compounds produced in Chile, Turkey, and the United States are listed in table 4.

World Review

Argentina.—In 2004, Argentina was the leading producer of boron minerals in South America. Borax Argentina S.A. (a subsidiary of Rio Tinto plc) was the country's leading producer of borates and exported to the United States (tables 6-7). Borax Argentina mined borates at four deposits—Tincalayu and Sijes in Salta Province, at more than 4,270 meters (m) (14,000 feet) above sea level, and two dry lake beds, Salars Cauchari and Diabillo in Jujuy Province at 3,370 m. Yacimiento de Boroato El Porvenir at the Salar Cauchari produces ulexite that grades 37% boron oxide. The Tincalayu Mine, originally developed in 1976, was Argentina's largest open pit operation and measured 1.5 km long, 500 m wide, and 100 m deep. Commercial borates mined were colemanite, hydroborocite, kernite, tincal, and ulexite. The clay overburden averages 50 m and typically overlies 30 to 40 m of ore. Tailings from the company's ulexite concentration operation were used as feedstock to supply 8,000 t of boric acid production.

Other borate producers in the Province of Juyuy included Processadora de Boratos Argentina S.A. (owned by Ferro Corp. and Canadian JEM Resources & Engineering, Inc.), which produced borates from 2-m-thick layers of tincal and ulexite interbedded with clay and lenses of inyoite; Cia Minera Gavenda S.A., which produced borates at the La Inundada Mine at Salar Cauchari from layers of ulexite up to 1 m thick that grade between 11% and 35% B_2O_3; and Triboro S.A., which operated the Irene Mine where ulexite was mined that contained between 11% and 35% B_2O_3. Other producers in Argentina were Coop. de Borateros, Moncholi y Guijarro, Ramiro Matinez, and Viento Blanco S.R.L.

China.—Shanghai's new maglev train was the first maglev line to operate commercially. Another maglev route was planned between Shanghai and Beijing to be ready for the 2008 Olympics (Cody, 2004).

Japan.—After four decades and $2.4 billion spent on research, Central Japan Railway officials planned a maglev line from Tokyo to Osaka. Track and train parts are being simplified and miniaturized to make mass production and maintenance cheaper. Experts concede that the trains use about three times more energy than the current bullet trains (Hall, 2004).

Turkey.—Turkey was the largest producer of boron ore in the world and was expanding plant capacity to produce boron compounds. Turkey has an estimated 29.1% share of the worldwide borate market. Annual boric acid production capacity was 100,000 metric tons per year (t/yr) at the new plant at Emet, 85,000 t/yr at a plant at Bandirma, and 35,000 t/yr at a plant at Kirka. A 48,000-t/yr borax pentahydrate plant, a 65,000-t/yr borax decahydrate plant, and a 10,000-t/yr anhydrous borax plant were located at Kirka. Other capacity included a 22,000-t/yr sodium perborate tetrahydrate plant and a 9,000-t/yr sodium perborate monohydrate plant at Bandirma. Borate mine capacity was available at Bigadic (180,000 t/yr of colemanite), Emet (660,000 t/yr of colemanite), and Mustafa Kemalpasa (480,000 t/yr of colemanite and ulexite). In addition, 800,000 t/yr of tincal was produced at Kirka

Current Research and Technology

Diamond that has a perfect carbon crystal lattice without defects or substitutions is colorless. Such diamond has a large band gap—meaning that the energy required to free an electron so it can move through the diamond lattice is high—and therefore is an excellent electrical insulator. But replacing some of the carbon atoms in the diamond lattice with boron—an impurity that produces the pretty blue color in some rare diamonds, including the famed Hope Diamond—transforms diamond into a p-type semiconductor. That's because boron has only three outer-shell electrons and can form only three of the four bonds that carbon normally does in the diamond lattice. The result is a missing electron or "hole" that can move freely through the crystal, allowing the diamond to conduct positive charge. Boron-doped diamond, which is normally a semiconductor, turns into a superconductor at low temperatures. Synthetic diamond containing about 3% boron becomes a superconductor at 4 K. Superconducting diamond could be useful for surgical blades with sensors that measure properties of the surrounding tissue. Another use could be the direct electrical detection of the binding of complementary deoxyribose nucleic acid (DNA) strands to the DNA-labeled diamond surface directly; the detection is currently done by measuring the change in electrical properties of the diamond film, thus eliminating the need for labor- and time-intensive labeling steps required by other biosensing methods. Boron-doped diamond could be used to fabricate diamond-based electronic devices that could resist heat and chemical attack. Diffusion of other light elements, such as boron, calcium, or lithium, might also be used to alter the color of natural corundum. Most synthetic diamond is grown by methods that use high-pressure, high-temperature growth chambers. Better control of impurities is possible using a low-pressure technique called chemical vapor deposition (CVD) where the carbon is deposited from a very pure gas. CVD allows the production of a wider variety of colored diamond by varying the gas composition. A combination of spectroscopy and photoluminescence spectroscopy can be used to distinguish the CVD gems from naturally occurring ones (Chemical & Engineering News, 2004; Yarnell, 2004).

A University of South Florida medical study confirmed that borates can control dust mites, the predominant cause of asthma attacks in children. Borates are already approved for household use in cleaners, fertilizers, insecticides, and insulation, so benefits to millions of asthma and allergy suffers could be immediate (Makely, 2004§).

Studies at the Physical Chemistry Institute at the Technical University of Freiberg, Germany, reported on the properties of borazane (BH_3NH_3), which is a potential hydrogen source. Borazane is a stable nontoxic solid with high hydrogen content. Hydrogen can be released in quantities of up to 15% by mass through direct thermal decomposition of the solid or by catalytic decomposition of aqueous borazane solutions. These properties have attracted Opel (a subsidiary of General Motors Corp.) to support the research in an effort to find a suitable method for hydrogen generation for use in fuel-cell-powered cars (Jacoby, 2004b).

Studies at the University of Los Angeles found a reduction of prostate cancer in men who eat a lot of boron. Diets that included two milligrams of boron had one-third the risk of prostate cancer compared with men whose diet contained only one milligram (Borax Pioneer, 2004).

Outlook

Historically, the housing market has been a leading consumer of boron minerals, notably for fiberglass insulation. Increased usage of ceramic tiles in kitchens and bathrooms will keep boron compound demand in the enamels, frits, and glazes end use strong in the short term and will likely increase as the overall size of the market for ceramic products grows (Stentiford, 2004). The boron industry is directly affected by the health of the glass industry. The demand in fiberglass insulation, the leading end use, was expected to decrease as other forms of insulation take market share away. Boron glass represented 70% of domestic demand and decreased by 2% in 2004 compared with 2003. Demand as a fertilizer will remain high. Imports of boron chemicals from Turkey are expected to grow because manufactured Turkish boron derivatives are expected to increase as supplies of boron minerals diminish from the market as the country produces more value-added products. New plants in Turkey for boric acid and sodium borate that are scheduled to come onstream may cause prices for boron derivatives to decline. Some automobile manufacturers have been replacing metal parts with reinforced fiberglass plastic parts to reduce weight and increase the efficiency of gasoline consumption. This would increase the demand for boron in reinforced composites. The demand for energy-efficient nonpolluting cars could cause increased demand for borates in fuel cells. A prototype car using a sodium borohydride fuel cell was displayed during 2003. A prototype titanium diboride battery demonstrated the potential to be superior to traditional zinc batteries; they could last twice as long as traditional carbon-zinc batteries or be one-half as large as other battery energy storage systems.

New technology could create a large demand for boron chemicals. New uses in automotive fuel cells also have the potential for creating strong demand. A new process in paper mills that recycles boron chemicals could increase demand at the mills and could reduce the effort needed to meet environmental requirements for waste and this would tend to lower paper production costs.

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TABLE 1

SALIENT STATISTICS OF BORON MINERALS AND COMPOUNDS[1]

(Thousand metric tons and thousand dollars)

	2000	2001	2002	2003	2004
United States:					
Sold or used by producers:					
Quantity:					
Gross weight[2]	1,070	1,050	1,050	1,150	1,210
B_2O_3 content	546	536	543 r	605 r	637
Value	557,000	506,000	513,000	591,000	626,000
Exports:[3]					
Boric acid:[4]					
Quantity	119	85	84	70	61
Value	64,400	47,000	44,600	36,400	34,900
Sodium borates:					
Quantity	413	221	150	131	135
Value	136,000	91,700	63,100	55,400	60,200
Imports for consumption:					
Borax:[3]					
Quantity	1	1	(5)	(5)	(5)
Value	716	642	94	19	62
Boric acid:[3]					
Quantity	39	56	49	47	49
Value	17,500	21,700	18,500	19,000	20,300
Colemanite:					
Quantity[6]	26	35	32	24	21
Value	7,410	9,790	8,960	6,960	6,070
Ulexite:					
Quantity[6]	127	109	125	80	110
Value	31,800	21,800	25,000	16,000	21,900
Consumption, B_2O_3 content	360	347	359	366 r	385
World, production	4,550	4,730	4,560 r	4,750 r	4,410 e

[e]Estimated. [r]Revised.

[1]Data are rounded to no more than three significant digits.

[2]Minerals and compounds sold or used by producers, including actual mine production, and marketable products.

[3]Source: U.S. Census Bureau.

[4]Includes orthoboric and anhydrous boric acid. Harmonized Tariff Schedule of the United States codes 2840.19.0000, 2840.30.0000, and 2840.20.0000.

[5]Less than ½ unit.

[6]Source: Journal of Commerce Port Import/Export Reporting Service.

TABLE 2
BORON MINERALS OF COMMERCIAL IMPORTANCE

Mineral[1]	Chemical composition	B_2O_3, weight percentage
Boracite (stassfurite)	$Mg_3B_7O_{13}Cl$	62.2
Colemanite	$Ca_2B_6O_{11}\cdot 5H_2O$	50.8
Datolite	$CaBSiO_4OH$	24.9
Hydroboracite	$CaMgB_6O_{11}\cdot 6H_2O$	50.5
Kernite (rasortie)	$Na_2B_4O_7\cdot 4H_2O$	51.0
Priceite (pandermite)	$CaB_{10}O_{19}\cdot 7H_2O$	49.8
Probertite (kramerite)	$NaCaB_3O_9\cdot 5H_2O$	49.6
Sassolite (natural boric acid)	H_3BO_3	56.3
Szaibelyite (ascharite)	$MgBO_2OH$	41.4
Tincal (natural borax)	$Na_2B_4O_7\cdot 10H_2O$	36.5
Tincalconite (mohavite)	$Na_2B_4O_7\cdot 5H_2O$	47.8
Ulexite (boronatrocalcite)	$NaCaB_5O_9\cdot 8H_2O$	43.0

[1]Parentheses include common names.

TABLE 3

U.S. CONSUMPTION OF BORON MINERALS AND COMPOUNDS, BY END USE[1, 2]

(Metric tons of B_2O_3 content)

End use	2003	2004
Agriculture	11,000	9,360
Borosilicate glasses	22,000	19,800
Enamels, frits, glazes	11,800	9,930
Fire retardants:		
Cellulosic insulation	12,700	12,700
Other	1,230	2,380
Insulation-grade glass fibers	177,000 r	178,000
Metallurgy	14	181
Miscellaneous uses	14,600	45,400
Nuclear applications	--	124
Soaps and detergents	15,400	18,300
Sold to distributors, end use unknown	33,700	27,000
Textile-grade glass fibers	66,800 r	61,900
Total	366,000 r	385,000

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes imports of borax, boric acid, colemanite, and ulexite.

TABLE 4
YEAREND PRICES FOR BORON MINERALS AND COMPOUNDS[1]

(Dollars per metric ton)

Product	Price, December 31, 2003	Price, December 31, 2004
Borax, technical, anhydrous, 99%, bulk, carload, works[2]	900-930	900-930
Borax, technical, anhydrous, 99%, bags, carload, works[2]	846	846
Borax, technical, granular, decahydrate, 99%, bags, carload, works[2]	378	378
Borax, technical, granular, decahydrate, 99.5%, bulk, carload, works[2]	374	374
Borax, technical, granular, pentahydrate, 99.5%, bags, carload, works[2]	426	426
Borax, technical, granular, pentahydrate, 99.5%, bulk, carload, work[2]	400-425	400-425
Boric acid, technical, granular, 99.9%, bags, carload, works[2]	836	836
Boric acid, technical, granular, 99.9%, bulk, carload, works[2]	788	788
Boric acid, United States Borax & Chemical Corp., high-purity anhydrous, 99% B_2O_3, 100-pound-bags, carlots[2]	1,996	1,996
Colemanite, Turkish, 42% B_2O_3, ground to a minus 70-mesh, free on board (f.o.b.) railcars, Kings Creek, SC[3]	270-290	270-290
Ulexite, Chilean, 38% B_2O_3, ground to a minus 6-mesh, f.o.b railcars, Norfolk, VA[e]	200	200

[e]Estimated.

[1]U.S. f.o.b. plant or port prices per metric ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations. Values have been rounded to the nearest dollar.

[2]Source: Chemical Market Reporter, v. 265, no. 1, January 2, 2004, p. 16; v. 267, no. 1, January 3, 2005, p. 20.

[3]Source: Industrial Minerals, no. 436, January 2004, p. 68; no. 448, January 2005, p. 72.

TABLE 5

U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY[1]

	2003			2004		
	Boric acid[2]		Sodium	Boric acid[2]		Sodium
	Quantity	Value	borates[3]	Quantity	Value	borates[3]
Country	(metric tons)	(thousands)	(metric tons)	(metric tons)	(thousands)	(metric tons)
Australia	2,120	$929	4,780	1,910	$849	4,530
Belgium	--	--	61	11	24	144
Brazil	2,950	1,210	3,010	890	525	1,700
Canada	4,990	3,270	45,700	5,180	3,580	44,500
China	11,800	4,950	20,800	9,630	4,510	23,000
Colombia	5	4	2,270	34	29	2,650
France	--	--	1	35	27	1
Germany	1,660	786	10	978	1,040	8
Hong Kong	614	339	395	6,230	2,740	449
India	--	--	434	1	3	100
Indonesia	550	323	457	1,090	587	3,080
Italy	32	47	2,400	2	7	2,560
Japan	17,500	10,700	17,900	14,600	9,780	18,000
Korea, Republic of	11,400	5,420	9,130	7,310	3,620	5,750
Malaysia	518	415	4,280	769	567	1,570
Mexico	1,350	883	3,780	3,030	1,730	7,730
Netherlands	11	7	2	11	7	3
New Zealand	164	57	2,040	445	184	2,560
Philippines	34	22	979	133	81	1,230
Singapore	697	371	612	822	436	1,290
Taiwan	9,770	4,520	4,600	5,030	2,480	3,800
Thailand	2,730	1,430	3,900	2,610	1,850	7,000
United Kingdom	81	243	2	7	35	1
Venezuela	56	54	179	75	77	240
Vietnam	57	27	887	172	84	759
Other	523	306	2,170	64	69	2,290
Total	69,600	36,400	131,000	61,000	34,900	135,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States (HTS) code 2810.00.0000.

[3]HTS codes 2840.19.0000, 2840.30.0000, and 2840.20.0000.

Source: U.S. Census Bureau.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF BORIC ACID, BY COUNTRY[1]

Country	2003 Quantity (metric tons)	2003 Value[2] (thousands)	2004 Quantity (metric tons)	2004 Value[2] (thousands)
Argentina	704	$305	1,340	$579
Australia	11	15	15	40
Bolivia	2,940	1,250	2,680	985
Chile	20,500	7,070	12,800	4,670
China	107	184	1	2
France	30	62	488	813
Germany	37	40	27	46
India	36	71	12	22
Italy	1,160	1,210	1,210	1,320
Japan	70	62	157	148
Korea, Republic of	72	26	18	7
Peru	3,690	1,440	4,340	1,610
Russia	8,370	3,530	411	179
Turkey	9,450	3,650	25,800	9,730
United Kingdom	38	68	78	115
Other	78	30	21	22
Total	47,300	19,000	49,400	20,300

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]U.S. customs declared values.

Source: U.S. Census Bureau.

TABLE 7

BORON MINERALS: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2000	2001	2002	2003	2004[e]
Argentina	513	634	510	545	560
Bolivia, ulexite	43 r	32	40 r	110 r	110
Chile, ulexite	338	328	431	401 r	401
China[e, 3]	145	150	145	130	135
Germany, borax[e]	1	1	1	1	1
Iran, borax[4]	4	3	2	3	3
Kazakhstan[e]	30	30	30	30	30
Peru	9	9	7	9	9 [5]
Russia[e, 6]	1,000	1,000	1,000	1,000	500
Turkey[7]	1,402	1,493	1,346	1,370 r	1,450
United States[8]	1,070	1,050	1,050	1,150	1,210
Total	4,550	4,730	4,560 r	4,750 r	4,410

[e]Estimated. [r]Revised.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals showi

[2]Table includes data available through May 20, 2005.

[3]B_2O_3 content.

[4]Data are for years beginning March 21 of that stated.

[5]Reported figure.

[6]Blended Russian datolite ore that reportedly grades 8.6% B_2O_3.

[7]Concentrates from ore.

[8]Minerals and compounds sold or used by producers, including both actual mine production and marketable products.